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IRRIGATION FRUIT TREES AND VINES

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Irrigation of fruit trees and vines: an introduction

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The anticipated population growth in the coming decades will place large, world wide demands to increase the global production of animal/fish protein, food, fiber, livestock feed and biofuels. This will put a tremendous strain on already stressed worldwide agricultural resources and declining arable land base. The current commodity surpluses are unlikely to last in the face of increasing population coupled with the worldwide decrease in ocean fisheries and the steady loss of productive lands due to soil erosion and degradation. Global climate change is further exacerbating the problems in ways that will have lasting impacts through changing temperatures and likely changes in annual rainfall amounts and regional distribution patterns.

Irrigation was initially developed to counter both short-term and long-term drought on crop production in arid and semi-arid areas when a reliable supplemental water supply was nearby. Over many centuries, irrigated lands have become fundamental to the world's food supply. It is estimated that there are now about 260 million irrigated hectares of land worldwide compared to less than 100 million ha in 1950. They constitute less than 17% of the world's total cultivated farmland but produce 40% of the food and fiber. Irrigated agricultural activities also provide considerable food and foraging sources for migratory and local birds as well as other wildlife. In short, irrigation underpins our modern world society and lifestyles.

Irrigation today is also the largest single consumer of water on the planet; accounting for about 20% of the total freshwater used and about two thirds of the total diverted for human uses. This development has not been without controversy or problems. Irrigation has had major environmental impacts on water quantity, and water and soil quality, and has permanently changed the social fabric of many regions around the world. In addition, there are ever increasing demands from other water user sectors to have greater access to this critical resource, including those representing recreational and other environmental concerns. Consequently, there is an urgent need to improve the management of irrigation water worldwide to conserve water, soil and energy, as well as to satisfy critical needs for both food and fiber and to address the needs of other user. Such improved management must shift the emphasis from production per unit area toward maximizing the production per unit water consumed by crops, also called water productivity (WP).

Traditionally, there have always been limited water transfers within irrigated agriculture to improve WP, normally through transfers at the farm or project level from field crops that have low WP to higher valued horticultural crops with higher WP. Economic factors have also spurred the transfer of agricultural water to municipal and industrial uses in many areas. However, as demands on the world's scarce freshwater supplies increase, water transfers from agriculture to other sectors will become more and more common; and, even mandated by judicial and legislative processes in some instances. Therefore, improving irrigation management in horticultural crops, such as fruit trees and vines, will be of paramount importance in optimizing the use of the limited resources.

Irrigation of fruit trees and vines not only provides some security in protecting a large investment with potentially high returns against droughts, but serves also to increase and stabilize production. In addition, it has been shown that proper irrigation practices can have a positive influence on the quality of the harvested produce and any resulting processed product. This last feature strongly affects net profits in several important crops and will have even more importance in the future.

Research around the world has developed many technical procedures for the quantitative management of irrigation in fruit trees and vines that not only influences

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quality but may also conserve substantial amounts of water over a season. Research has also shown irrigation management to be the largest, most controllable factor in determining grape and wine quality in arid areas. However, due perhaps to the need for substantial investments in management capacity as well as improving or replacing irrigation systems, the majority of growers worldwide still manage irrigation applications based on either rigid calendars determined by external factors such as rotation delivery schedules, or, at best, on qualitative observations. Nevertheless, external pressures will likely force changes by producers as water becomes more expensive and scarce, and as fruit quality becomes much more relevant in determining profits. Already the potential impact of soil water management on fruit quality and producer profits has been demonstrated in the wide range (almost an order of magnitude!) of prices paid for wine grapes within a given region, partly as a result of irrigation practices of those growers. Another case is the highly regarded wine industry in eastern Washington and Oregon in the USA that would not be possible without exacting irrigation water management programs to ensure winter hardiness.

Recent advances in fruit tree and vine production have been based on the intensification of a number of techniques, from higher tree density and new options for canopy management to faster paced introduction of new cultivars and increased fertigation through microirrigation. The diversity of production environments in the Northern and Southern Hemispheres has led to a nearly constant supply of fresh fruit year round, while the many new production techniques now available require more precise site-specific management. As an example, the supplemental irrigation of traditional olive plantations of less that 100 trees ha^{-1} has little in common with the full irrigation of modern, intensive olive plantations in arid areas of 1,000–2,000 trees ha^{-1}. However, in both these instances and in every other case, scientific irrigation scheduling will require: (a) an estimate of crop water use; (b) knowledge of the crop response to water deficits for stress management and; (c) a method to detect the timing of irrigation or to monitor the level of stress. Reported in this Special Issue of *Irrigation Science* are research results, obtained in a variety of crops and environments, which pertain to these three areas.

For example, crop water use has traditionally been determined using an estimate of reference water use and appropriate crop coefficients. In the case of fruit trees, a canopy coefficient is needed to account for less than full radiation interception due to either tree age or to canopy management. Goodwin et al., *this issue*, measured the water use of a peach tree and related it to intercepted radiation with the aim of calculating tree transpirational water use as a function of reference water use and ground shaded area. Testi et al., *this issue*, developed and validated a complete model of olive orchard water use that calculates independently transpiration, evaporation from the soil, and interception of rainfall. The model is then used in a second paper (Testi et al., *this issue*) to develop sets of monthly crop coefficients for irrigation scheduling of orchards that vary in tree density, canopy volume, frequency of irrigation, and other factors. Irrigation management in fruit trees aims at maintaining adequate water supplies at all times by appropriate scheduling that avoids tree water deficits. Initially, modern irrigation scheduling practices for fruit trees were largely developed on deep valley soils whose stored soil water compensated for errors in scheduling. However the need for accurate scheduling has increased substantially as new plantations have been established in less than ideal soils with low water holding capacity and as high frequency, microirrigation methods were introduced. Thus, new methods of determining orchard water requirements presented in this issue's papers should lead to more precise irrigation management.

The need for more accurate scheduling and precise application is also shown in the increasing body of practical experience and experimental evidence indicating that supplying the full requirements to tree crops and vines may not be the best irrigation strategy in many situations. This is certainly the case in the irrigation of wine grapes. The imposition of water stress on certain developmental periods aimed at reducing water use while maintaining or even increasing farm net profits, has been termed regulated deficit irrigation (RDI) and has been extensively researched in the main fruit tree crops over the last two decades. In *this issue*, Leib et al., characterizes the response of apples to two RDI regimes that did not differ in the amount of water applied. Both the deficit irrigation and the partial root drying regimes allowed for significant reductions in the amount of applied water relative to a full irrigated control, without significant reductions in yield and fruit size. Goldhamer et al., *this issue*, studied for four seasons the effects of nine different irrigation regimes on the production of mature almond trees with the objective of identifying successful RDI programs for almond orchards in California. The research reported by Goldhamer et al. is a prerequisite for the successful implementation of RDI, because it provides the information needed to avoid errors in the design of RDI programs. Such errors could lead to yield losses and to the perception that RDI is not a feasible option for irrigation management.

Regardless of whether full or deficit irrigation programs are sought, there will always be the need for plant or soil water status indicators. The first indicators were based on monitoring soil water status, but more recently, monitoring the plant water potential is the established method for detecting water stress in fruit trees and vines. Girona et al., *this issue*, used different levels of leaf water potential to schedule irrigation in a commercial vineyard of the cultivar 'Pinot Noir'. The method proved useful to account for the spatial variability of soil water holding capacity when scheduling different experimental blocks. The experiment also confirmed the beneficial effects of water stress on certain aspects of grape production that influence wine quality.

One important limitation of all water stress indicators is the variability of the different indicators in use which may impact on the decision making process. Naor et al., *this issue*, examined the variability of plant water potentials, stem shrinkage and soil water potential measurements in apple, nectarine and pear orchards and determined the appropriate number of replicate measurements of stem water potential to characterize the water status of commercial apple orchards. More and more, the use of water stress indicators are becoming accepted as useful diagnostic tools by consultants and large farm managers. However, there is still a significant gap between current irrigation practices and what may be considered best management practices in most cases. Boland et al., *this issue*, report on an important extension effort to close that gap, based on studying the behavior of growers and their motivations for adopting improved practices. Their conclusion is that water savings are not the key incentive for growers to improve irrigation management, but that other potential benefits must be demonstrated too, before increased adoption occurs.

As we look ahead, we believe freshwater will be the major natural resource issue of the twenty first Century. It is also our belief that there will be large economic and social pressures to reduce irrigation water use while greatly increasing water productivity to feed and clothe the world. In addition, irrigation enterprises of the future will most likely be subjected to ever more rigorous environmental requirements. This is a major shift from the current emphasis on maximizing yield per unit area, and it will require a significant re-thinking of how and why irrigation is done. Hopefully, this special edition of *Irrigation Science* will lend some insight and, perhaps, some impetus to improving water management on tree and vine crops.

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